

CLAIMS

- [c1] 1. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:
- a workpiece holder configured to receive a microelectronic workpiece;
 - a workpiece electrode configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;
 - a first remote electrode and a second remote electrode, the first and second remote electrodes being spaced apart from the workpiece holder;
 - a mechanical medium having a bearing surface facing the workpiece holder and a backside facing the first and second remote electrodes;
 - an AC power supply;
 - a DC power supply; and
 - a switching assembly coupled to the workpiece electrode, the first remote electrode, the second remote electrode, the AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the AC power supply and/or the DC power supply to the workpiece electrode, the first remote electrode, and/or the second remote electrode.
- [c2] 112 2. The apparatus of claim 1 wherein the first electrode is carried by the workpiece holder. *holder*
- [c3] 3. The apparatus of claim 1 wherein:
- MA* the first electrode is carried by the workpiece holder; and
 - the first remote electrode and the second remote electrode are carried by a remote electrode assembly separate from the workpiece holder.

[c4]

4. The apparatus of claim 1 wherein:
the workpiece holder comprises a substrate carrier having a chuck
configured to hold the workpiece so that the processing side faces
downward and a drive assembly coupled to the substrate carrier to
move the substrate carrier; and
the workpiece electrode is carried by the workpiece holder.

[c5]

5. The apparatus of claim 1 wherein:
the workpiece holder comprises a substrate carrier having a chuck
configured to hold the workpiece so that the processing side faces
upward and a drive assembly coupled to the substrate carrier to
move the substrate carrier; and
the workpiece electrode is carried by the workpiece holder.

[c6]

6. The apparatus of claim 1, further comprising an electrode assembly
spaced apart from the workpiece holder, and wherein the first remote electrode
and the second remote electrode are carried by the electrode assembly.

[c7]

7. The apparatus of claim 1 wherein:
the apparatus further comprises a moveable electrode assembly spaced
apart from the workpiece holder, the electrode assembly being
moveable relative to the workpiece holder; and
the first remote electrode and the second remote electrode are carried by
the electrode assembly.

[c8]

8. The apparatus of claim 1 wherein:
the apparatus further comprises a moveable electrode assembly spaced
apart from the workpiece holder, the electrode assembly being
moveable relative to the workpiece holder;

the first remote electrode and the second remote electrode are carried by the electrode assembly; and
the mechanical medium comprises a first polishing pad carried by the first remote electrode and a second polishing pad carried by the second remote electrode.

[c9] 9. The apparatus of claim 1 wherein:
the apparatus further comprises a table;
the mechanical medium comprises a polishing pad carried by the table;
the workpiece holder is positioned over the polishing pad, and the workpiece electrode is carried by the workpiece holder; and
the first remote electrode and the second remote electrode are carried by the table.

[c10] 10. The apparatus of claim 1, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrochemical processing solution, (b) applying a direct electrical current to the workpiece electrode and at least one of the first remote electrode and/or the second remote electrode while the workpiece contacts the electrochemical processing solution, (c) applying an alternating electrical current to at least one of the first remote electrode and/or the second remote electrode while the workpiece contacts the electrochemical processing solution, and (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current.

[c11] 11. The apparatus of claim 1, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrochemical processing solution, (b)

applying a direct electrical current to the workpiece electrode and at least one of the first remote electrode and/or the second remote electrode while the workpiece contacts the electrochemical processing solution, (c) applying an alternating electrical current to the first remote electrode and the second remote electrode while the workpiece contacts the electrochemical processing solution, and (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current.

[c12] 12. The apparatus of claim 1, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrochemical processing solution, (b) applying a direct electrical current to the workpiece electrode and at least one of the first remote electrode and/or the second remote electrode while the workpiece contacts the electrochemical processing solution, (c) applying an alternating electrical current to the first remote electrode and the second remote electrode while applying the direct electrical current.

[c13] 13. The apparatus of claim 1, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrochemical processing solution, (b) applying a direct electrical current to the workpiece electrode and at least one of the first remote electrode and/or the second remote electrode while the workpiece contacts the electrochemical processing solution, (c) applying an alternating electrical current to the first remote electrode and the second remote electrode while the workpiece contacts the electrochemical processing solution, (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current, and (e) moving the at least one of the workpiece and/or the first and second remote electrodes so that the first and the

second remote electrodes have a higher dwell time at a first region of the workpiece than at a second region.

[c14] 14. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:

a workpiece holder configured to receive a microelectronic workpiece;
a workpiece electrode configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;
a first remote electrode and a second remote electrode, wherein the first and second remote electrodes are juxtaposed to the workpiece holder to be spaced apart from the processing side of the workpiece when the workpiece is received in the workpiece holder;
an AC power supply;
a DC power supply; and
a switching assembly coupled to the workpiece electrode, the first remote electrode, the second remote electrode, the AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the AC power supply and/or the DC power supply to the workpiece electrode, the first remote electrode, and/or the second remote electrode.

[c15] 15. The apparatus of claim 14 wherein the workpiece electrode is carried by the workpiece holder, and wherein the apparatus further comprises a mechanical medium having a bearing surface facing the workpiece holder and a backside facing the first and second remote electrodes.

[c16] 16. The apparatus of claim 15 wherein:
the workpiece electrode is carried by the workpiece holder; and
the first remote electrode and the second remote electrode are carried by an electrode assembly separate from the workpiece holder.

[c17] 17. The apparatus of claim 15, further comprising an electrode assembly spaced apart from the workpiece holder, and wherein the first and second remote electrodes are carried by the electrode assembly.

[c18] 18. The apparatus of claim 15 wherein:
the apparatus further comprises a moveable electrode assembly spaced apart from the workpiece holder, wherein the electrode assembly is moveable relative to the workpiece holder; and
the first and second remote electrodes are carried by the electrode assembly.

[c19] 19. The apparatus of claim 15 wherein:
the apparatus further comprises a moveable electrode assembly spaced apart from the workpiece holder;
the first and second remote electrodes are carried by the electrode assembly; and
the mechanical medium comprises a first polishing pad carried by the first remote electrode and a second polishing pad carried by the second remote electrode.

[c20] 20. The apparatus of claim 15 wherein:
the apparatus further comprises a table;
the mechanical medium comprises a polishing pad carried by the table;
the workpiece holder is positioned over the polishing pad, and the workpiece electrode is carried by the workpiece holder; and
the first and second remote electrodes are carried by the table.

[c21] 21. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:
a workpiece holder configured to receive a microelectronic workpiece;

a first electrode configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;

a second electrode and a third electrode, the second and third electrodes being remote electrodes that are spaced apart from the workpiece holder;

a mechanical medium between the workpiece holder and each of the second and third electrodes;

an AC power supply;

a DC power supply; and

a switching assembly coupled to the first electrode, second electrode, third electrode, AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the AC power supply and/or the DC power supply to the first, second, and/or third electrodes.

[c22] 22. The apparatus of claim 21 wherein the first electrode is carried by the workpiece holder.

[c23] 23. The apparatus of claim 21 wherein:

the first electrode is carried by the workpiece holder; and

the second and the third electrodes are carried by an electrode assembly separate from the workpiece holder.

[c24] 24. The apparatus of claim 21 wherein:

the workpiece holder comprises a substrate carrier having a chuck configured to hold the workpiece so that the processing side faces downward and a drive assembly coupled to the substrate carrier to move the substrate carrier; and

the first electrode is carried by the workpiece holder.

[c25] 25. The apparatus of claim 21 wherein:
the workpiece holder comprises a substrate carrier having a chuck
configured to hold the workpiece so that the processing side faces
upward and a drive assembly coupled to the substrate carrier to
move the substrate carrier; and
the first electrode is carried by the workpiece holder.

[c26] 26. The apparatus of claim 21, further comprising an electrode assembly
spaced apart from the workpiece holder, and wherein the second and the third
electrodes are carried by the electrode assembly.

[c27] 27. The apparatus of claim 21 wherein:
the apparatus further comprises a moveable electrode assembly spaced
apart from the workpiece holder; and
the second and the third electrodes are carried by the electrode assembly.

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[c28] 28. The apparatus of claim 21 wherein:
the apparatus further comprises a moveable electrode assembly spaced
apart from the workpiece holder;
the second and the third electrodes are carried by the electrode assembly;
and
the mechanical medium comprises a first polishing pad carried by the
second electrode and a second polishing pad carried by the third
electrode.

[c29] 29. The apparatus of claim 21 wherein:
the apparatus further comprises a table;
the mechanical medium comprises a polishing pad carried by the table;
the workpiece holder is positioned over the polishing pad, and the first
electrode is carried by the workpiece holder; and

the second and the third electrodes are carried by the table.

[c30] 30. The apparatus of claim 21, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrolytic solution, (b) applying a direct electrical current to the first electrode and at least one of the second and/or the third electrodes while the workpiece contacts the electrolytic solution, (c) applying an alternating electrical current to at least one of the second and/or the third electrodes while the workpiece contacts the electrolytic solution, and (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current.

[c31] 31. The apparatus of claim 21, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrolytic solution, (b) applying a direct electrical current to the first electrode and at least one of the second and/or the third electrodes while the workpiece contacts the electrolytic solution, (c) applying an alternating electrical current to the second and the third electrodes while the workpiece contacts the electrolytic solution, and (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current.

[c32] 32. The apparatus of claim 21, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrolytic solution, (b) applying a direct electrical current to the first electrode and at least one of the second and/or the third electrodes while the workpiece contacts the electrolytic solution, (c) applying

an alternating electrical current to the second and the third electrodes while applying the direct electrical current.

[c33] 33. The apparatus of claim 21, further comprising a controller having a computer operable medium containing instructions to operate the apparatus according to a process comprising (a) contacting the processing side of the microelectronic workpiece with an electrolytic solution, (b) applying a direct electrical current to the first electrode and at least one of the second and/or the third electrodes while the workpiece contacts the electrolytic solution, (c) applying an alternating electrical current to the second and the third electrodes while the workpiece contacts the electrolytic solution, (d) pressing the processing side of the workpiece against the mechanical medium at least while applying the alternating current, and (e) moving the at least one of the workpiece and/or the second and third electrodes so that the second and the third electrodes have a higher dwell time at a first region of the workpiece than at a second region.

[c34] 34. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:

- a workpiece holder configured to receive a microelectronic workpiece;
- a workpiece electrode configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;
- a first remote electrode and a second remote electrode, the first and second remote electrodes being spaced apart from the workpiece holder;
- a mechanical medium between the workpiece holder and each of the first and second remote electrodes;
- an AC power supply;
- a DC power supply; and

a switching assembly coupled to the workpiece electrode, first remote electrode, second remote electrode, AC power supply, and the DC power supply; and

a controller coupled to the switching assembly, the controller including a computer operable medium containing instructions to operate the switching assembly according to a process including (a) coupling the workpiece electrode and at least one of the first and second remote electrodes to the DC power supply, and/or (b) coupling the first and second remote electrodes to the AC power supply.

[c35]

35. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:

a workpiece holder configured to receive a microelectronic workpiece;

a workpiece electrode configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;

a first remote electrode and a second remote electrode, the first and second remote electrodes being spaced apart from the workpiece holder;

a mechanical medium between the workpiece holder and each of the first and second remote electrodes;

an AC power supply;

a DC power supply; and

a switching assembly coupled to the workpiece electrode, first remote electrode, second remote electrode, AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the workpiece electrode and at least one of the first and/or second remote electrodes to the DC power supply, and further wherein the switching assembly is configured to selectively couple at least the first and second remote electrodes to the AC power supply.

[c36]

36. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:

- a workpiece holder configured to receive a microelectronic workpiece;
- a workpiece electrode carried by the workpiece holder, the workpiece electrode being configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;
- a material removal device including an electrode assembly facing the workpiece holder, a first remote electrode carried by the electrode assembly, a second remote electrode carried by the electrode assembly, and a mechanical medium carried by the first and second remote electrodes, wherein the first and second remote electrodes are spaced apart from the workpiece holder;
- an AC power supply;
- a DC power supply; and
- a switching assembly coupled to the workpiece electrode, first remote electrode, second remote electrode, AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the AC power supply and/or the DC power supply to the workpiece electrode, the first remote electrode, and/or the second remote electrode.

[c37]

37. An apparatus for electrochemical-mechanical processing of microelectronic workpieces, comprising:

- a workpiece holder configured to receive a microelectronic workpiece;
- a workpiece electrode carried by the workpiece holder, the workpiece electrode being configured to contact a processing side of the workpiece when the workpiece is received in the workpiece holder;
- a material removal device including an electrode assembly facing the workpiece holder, a first remote electrode carried by the electrode assembly, a second remote electrode carried by the electrode

assembly, and a mechanical medium carried by the first and second remote electrodes, wherein the electrode assembly is moveable to move the first and second remote electrodes relative to the workpiece holder;

an AC power supply;

a DC power supply; and

a switching assembly coupled to the workpiece electrode, first remote electrode, second remote electrode, AC power supply, and the DC power supply, wherein the switching assembly is configured to selectively couple the AC power supply and/or the DC power supply to the workpiece electrode, the first remote electrode, and/or the second remote electrode.

[c38] 38. A method of electrochemical-mechanical processing of microelectronic workpieces, comprising:

contacting a processing side of a microelectronic workpiece with an electrolytic solution;

applying a direct electrical current to a workpiece electrode contacting the processing side of the workpiece and a first remote electrode, the workpiece electrode and the first remote electrode being in electrical communication with the electrolytic solution;

applying an alternating current to the first remote electrode and a second remote electrode, the first and second remote electrodes being in electrical communication with the electrolytic solution; and

contacting the processing side of the workpiece with a mechanical medium at least while applying the alternating current to the first and second remote electrodes.

[c39] 39. A method of electrochemical-mechanical processing of microelectronic workpieces, comprising:

contacting a processing side of a microelectronic workpiece with an electrolytic solution;

applying a direct electrical current to a workpiece electrode contacting the processing side of the workpiece and at least one of a first remote electrode and/or a second remote electrode, the workpiece electrode, the first remote electrode, and the second remote electrode being in electrical communication with the electrolytic solution;

applying an alternating current to the first and second remote electrodes; and

contacting the processing side of the workpiece with a mechanical medium at least while applying the alternating current to the first and second remote electrodes.

[c40] 40. A method of electrochemical-mechanical processing of microelectronic workpieces, comprising:

contacting a processing side of a microelectronic workpiece with an electrolytic solution;

applying a direct electrical current to a workpiece electrode in contact with the processing side of the workpiece and at least one of a first remote electrode and/or a second remote electrode, wherein the workpiece electrode, the first remote electrode, and the second remote electrode are in electrical communication with the electrolytic solution; and

applying an alternating current to the first and second remote electrodes while applying the direct current.

[c41] 41. A method of electrochemical-mechanical processing of microelectronic workpieces, comprising:

contacting a processing side of a microelectronic workpiece with an electrolytic solution;

applying a direct electrical current to a workpiece electrode contacting the processing side of the workpiece and at least one of a first remote electrode and/or a second remote electrode, the workpiece electrode, the first remote electrode, and the second remote electrode being in electrical communication with the electrolytic solution;

applying an alternating current to the first and second remote electrodes while applying the direct current; and

moving at least one of the microelectronic workpiece and/or the first and second remote electrodes relative to each other while applying the direct current and the alternating current so that the first and second remote electrodes have a higher dwell time at a first region of the workpiece than at a second region of the workpiece.

[c42] 42. A method of electrochemical-mechanical processing of microelectronic workpieces, comprising:

contacting a processing side of a microelectronic workpiece with an electrolytic solution;

applying a direct electrical current to a workpiece electrode that is in contact with the processing side of the workpiece and at least one of a first remote electrode and/or a second remote electrode, the workpiece electrode, the first remote electrode, and the second remote electrode being in electrical communication with the electrolytic solution;

applying an alternating current to the first and second remote electrodes while applying the direct current; and

moving at least one of the microelectronic workpiece and/or the first and second remote electrodes relative to each other while applying the direct current and the alternating current so that the first and second remote electrodes have a higher dwell time at regions of the workpiece having a thicker layer of plated material.

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